Exploring the Progression of Cognitive Functioning in Patients with Dementia

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Introduction

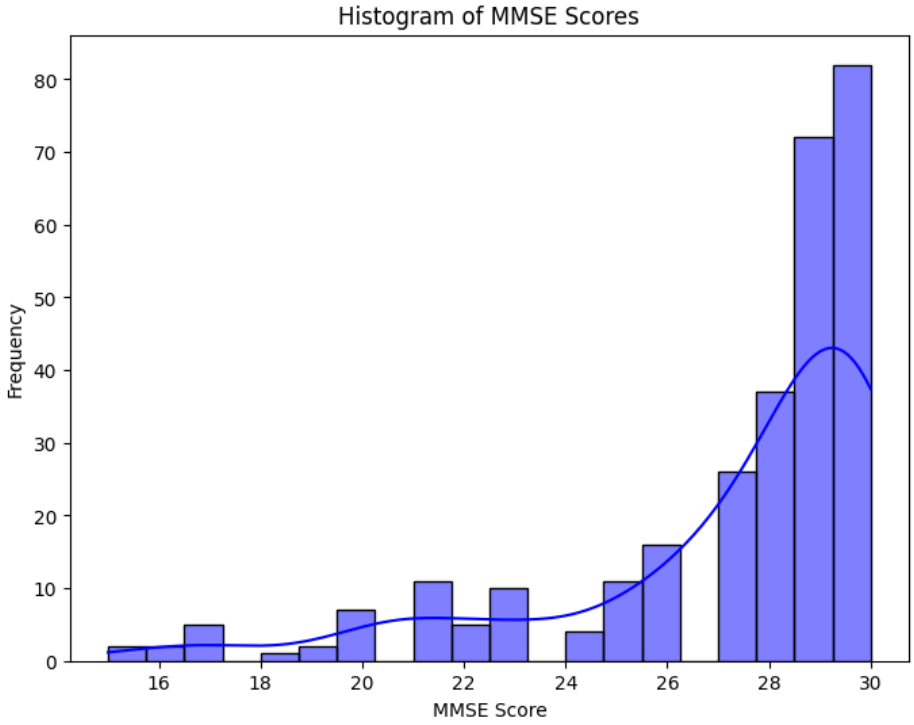
In this study, we delve into the longitudinal assessment of cognitive functioning in patients with dementia by analyzing a subset of MRI data obtained from a larger longitudinal study. Our primary objective is to investigate how cognitive functioning, as measured by the Mini-Mental State Examination (MMSE) scores, evolves over time among individuals with and without dementia. Through a mixed-effects analysis of variance (ANOVA) approach, we aim to uncover potential differences in the trajectory of cognitive decline between these two groups. The research questions are as follows:

1. How does cognitive functioning, as indicated by MMSE scores, change over multiple visits among individuals with dementia compared to those without dementia?
2. Are there significant differences in the trajectory of MMSE scores between patients with dementia and those without dementia?

Exploratory Data Analysis

We created a histogram to look at the distribution of MMSE scores. The scores do not appear to be normally distributed.

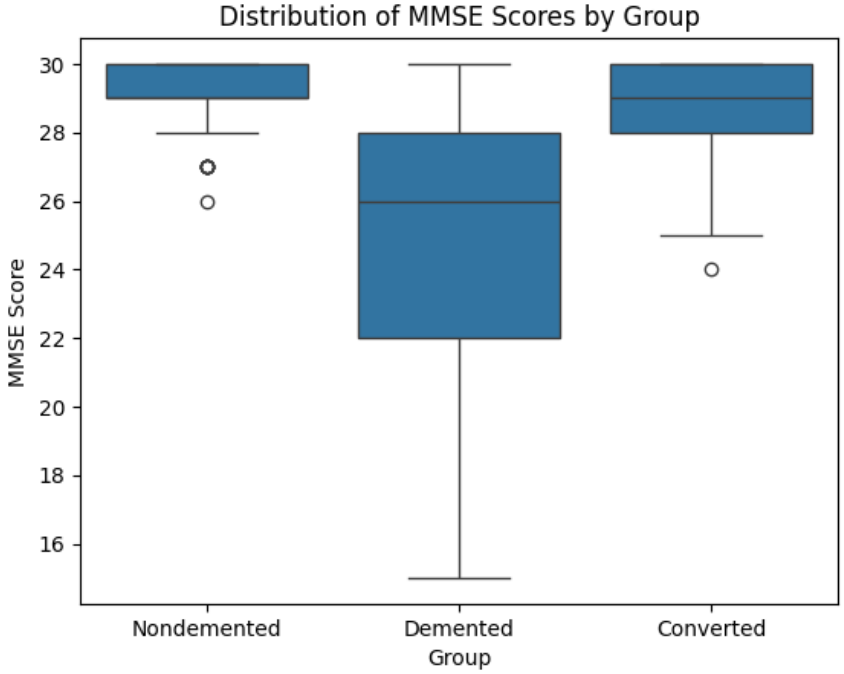
Figure 1: Histogram of MMSE Scores



We created a boxplot to look at the distribution of Mini-Mental State Examination (MMSE) scores across three groups: Nondemented, Demented, and Converted. The median MMSE score, indicated by the line within each box, differs across groups. The

'Nondemented' group has a higher median score compared to the 'Demented' group, suggesting better cognitive function. The 'Converted' group, potentially referring to individuals who have transitioned from a nondemented to a demented cognitive state, shows a median score between the other two groups.

Figure 2: Boxplot of MMSE Scores by Group



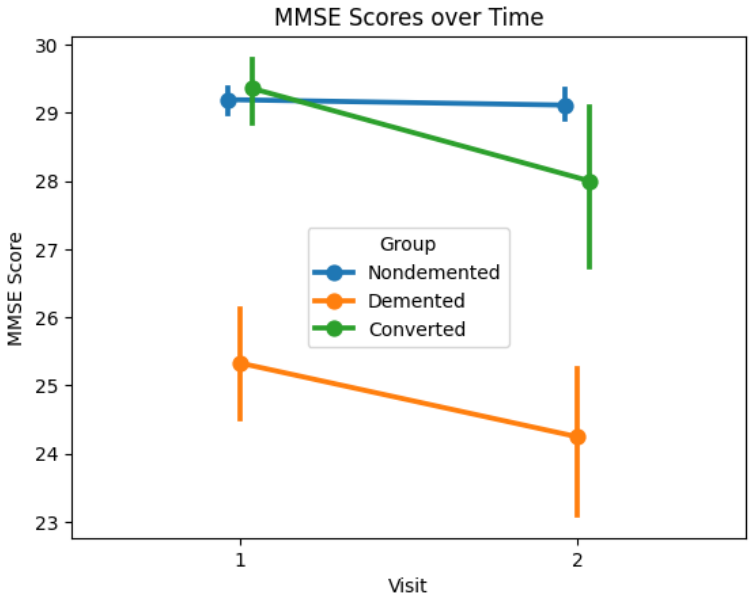
After conducting exploratory data analysis, including visualization of MMSE scores by group, we proceeded to test the normality assumption using the Shapiro-Wilk test. The results revealed that the distribution of MMSE scores within each group significantly deviated from normality (Nondemented: $W=0.81$, $p<0.001$; Demented: $W=0.93$, $p<0.001$; Converted: $W=0.77$, $p<0.001$). These findings indicate that the MMSE scores do not follow a normal distribution within any of the groups, which is an important consideration for subsequent statistical analyses.

Chart 1: Shapiro-Wilk Test for Normality

Group	W	p-value	normal
Nondemented	0.809528	2.635762e-12	False
Demented	0.929083	5.677786e-06	False
Converted	0.770938	5.867723e-05	False

We also created an interaction plot of MMSE Scores over time, between 'Nondemented', 'Demented', and 'Converted' groups.

Figure 3: MMSE Scores Over Time



Quantitative Analysis

The mixed-effects ANOVA revealed significant main effects for both the 'Group' factor ($F(2, 140) = 56.21$, $p < 0.001$, $\eta p^2 = 0.45$) and the 'Visit' factor ($F(1, 140) = 8.86$, $p = 0.003$, $\eta p^2 = 0.06$), indicating that both dementia status and visit number significantly influenced MMSE scores. Additionally, there was a significant interaction effect between 'Group' and 'Visit' ($F(2, 140) = 3.37$, $p = 0.037$, $\eta p^2 = 0.05$), suggesting that the rate of change in MMSE scores varied between dementia and nondementia groups across different visits.

Chart 2: ANOVA Table

Source	SS	DF1	DF2	MS	F	p-unc	np2	eps
Group	1328.42	2	140	664.21	56.21	1.20e-18	0.45	NaN
Visit	22.38	1	140	22.38	8.86	3.44e-03	0.06	1.0
Interaction	17.00	2	140	8.50	3.37	3.74e-02	0.05	NaN

Post-Hoc Tests

Post hoc tests were conducted to further explore these effects. Pairwise comparisons between dementia and nondementia groups at different visits revealed significant differences in MMSE scores. Specifically, converted individuals showed significantly higher scores compared to both demented ($t(142) = 6.739$, $p < 0.001$, Cohen's $d = 1.167$) and non-demented ($t(64.318) = -9.449$, $p < 0.001$, Cohen's $d = -1.754$) individuals. Moreover, significant differences were observed between demented and non-demented individuals at both visit 1 ($t(60.516) = 8.012$, $p < 0.001$, Cohen's $d = 1.314$) and visit 2 ($t(66.849) = -9.016$, $p < 0.001$, Cohen's $d = -1.668$), indicating varying trajectories of cognitive decline between these groups.

Chart 3: Post-Hoc Test

	Contrast	Visit	A	B	Paired
0	Visit	-	1	2	True
1	Group	-	Converted	Demented	False
2	Group	-	Converted	Non-demented	False
3	Group	-	Demented	Non-demented	False
4	Visit * Group	1	Converted	Demented	False
5	Visit * Group	1	Converted	Non-demented	False
6	Visit * Group	1	Demented	Non-demented	False
7	Visit * Group	2	Converted	Demented	False
8	Visit * Group	2	Converted	Non-demented	False
9	Visit * Group	2	Demented	Non-demented	False

	Parametric	T	dof	alt	p-unc	BF10	Hedges
0	True	2.928	142.000	2-sided	3.973e-03	5.53	0.162
1	True	6.739	51.064	2-sided	1.399e-08	2.036e+06	1.167
2	True	-1.303	12.315	2-sided	2.165e-01	0.599	-0.584
3	True	-9.449	64.318	2-sided	8.946e-14	2.207e+13	-1.754
4	True	8.012	60.516	2-sided	4.424e-11	3.187e+08	1.314
5	True	0.489	13.999	2-sided	6.327e-01	0.336	0.167
6	True	-9.016	66.849	2-sided	3.652e-13	2.117e+12	-1.668
7	True	4.548	33.888	2-sided	6.618e-05	759.706	0.899
8	True	-1.816	11.802	2-sided	9.491e-02	1.126	-0.937
9	True	-8.463	64.937	2-sided	4.430e-12	1.106e+11	-1.570

Power Analysis

Power analysis was conducted to determine the appropriate sample size for a theoretical experiment with an alpha level of 0.05, desired power of 0.91, and effect size of 0.7. Using the calculated effect size, alpha level, and desired power, a sample size of approximately 45 participants per group was determined. This ensures sufficient statistical power to detect significant differences in MMSE scores between groups with dementia and those without dementia. Adequate sample sizes are crucial for robust and reliable statistical analyses, enhancing the validity and generalizability of research findings.

Conclusion

In conclusion, the study affirms that cognitive functioning, as measured by MMSE, does not remain static over successive visits and that the degree of cognitive decline is not uniform across diagnostic groups. This differential trajectory of cognitive decline has substantive implications, particularly in tailoring interventions and monitoring their effectiveness over time. It is to be noted that the MMSE scores did not adhere to a normal distribution within any group, as evidenced by the Shapiro-Wilk test results. This deviation from normality necessitates a cautious interpretation of the ANOVA results and suggests that future research might benefit from employing alternative statistical approaches that do not presuppose normal distribution, such as non-parametric methods or data transformation techniques.